Lateral Placement of Vehicles on Urban Arterials under Mixed Traffic Conditions

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Abstract -Traffic scenario in the south-east Asian countries is predominantly of higher degree of heterogeneity. The lane following behavior of traffic is hardly seen in the Indian traffic conditions. Vehicles interact laterally as well as longitudinally, which mainly affects the overall throughput of the roadway system. The operating speeds of vehicles are considerably affected due to this lateral interaction of vehicles. Hence, it is necessary to study the lateral behavior of vehicles especially operating on urban roads. But, to study these interactions thoroughly on micro level is very difficult from field. Also, desired degree of precision cannot be obtained from the manual data collection measures. Hence, to study and analyse these interactions, a simulation model was prepared. State of the art multimodal traffic simulation software PTV VISSIM was used for modelling the traffic.

The model was calibrated with the speed, flow and density data that obtained from the field. The field data for a mid-block stretch was collected from the Pamposh Enclave intercity arterial road, by video-graphic method of data collection. High quality wide lenses camera was used to record the video from field. The data was further extracted on a wide screen camera in the laboratory and the main fundamental parameters of traffic namely speed, flow and density were extracted. Avidemux 4.1.1 software was used to further divide one second into ten microseconds, for more accurate readings of time data. The speed was calculated by recording the entry and exit times of each categories of vehicles, within the study stretch. Further the speed-flow, speed-density and flow-density relationships were developed from the collected dataset and the capacity of the road section was estimated using Green shields model, and it was found to be 5957 veh/hr. The running volume of the traffic and the capacity of the section were used to establish the volume to capacity (v/c) ratio of the section, in order to establish the level of service of the road section. The v/c ratio of the study stretch was obtained as 0.91, resulting the LOS of the system as E. Further, the whole vehicular traffic in number of vehicles per hour was converted in to the homogenous unit of traffic as, equivalent number of passenger cars per hour (PCU/hr.). The SC was considered as the standard car in the present study and all other types of vehicles were converted into equivalent number of SC per hour. The PCU values for all types of vehicles were estimated and the capacity of roadway was estimated as 6034 PCU/hr. The calibrated model was validated for two other similar road sections from Delhi region.

Key Words: PTV VISSIM, speed-density, Green shields model, LOS, passenger cars per hour

1. INTRODUCTION

South-East Asian countries like Sri-Lanka, Vietnam, Nepal, and Bangladesh including India have mixed traffic with higher degree of heterogeneity. The congestions observed especially in the urban regions due to increased vehicular ownership is another cause for these problems. In a proper lane following based traffic, the interaction of vehicles is mainly longitudinal (following). But, in case of heterogeneous traffic vehicles not only interact longitudinally but also laterally (frequent lane changes). This lane changing heterogeneous nature of traffic is natural and not possible to improve or understand by performing the experiments on field. However, simulating this type of nature of traffic in to a computer-based model, and then to analyse, understand the complexities will be much easier. This can be helpful to study the interactions between vehicles on micro level. Simulation being a very cost-effective solution for such problems, it is widely used around the globe for traffic modelling, analysis, forecasting purposes. Various software packages with attractive animations and user-friendly interface with efficient result obtaining capabilities are now available which attracts the transportation professionals to make use of them. Simulation of traffic helps to model the real-world traffic into a framework where we can modify the traffic and roadway conditions, driver's behaviour of desired vehicles, etc. to model a heterogeneous traffic, prevailing in urban regions of India, it is important to understand the speed maintaining behaviour, lateral interactions of traffic, acceleration and deceleration characteristics of traffic, etc.

2. Material and Methods

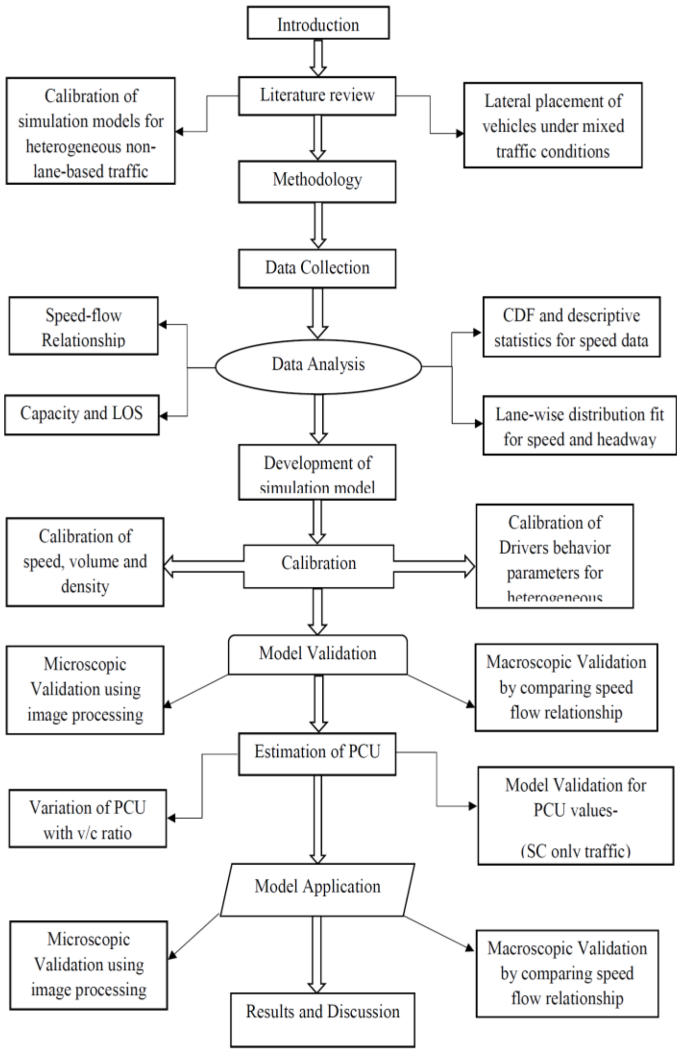

Fig. 1: Methodological flowchart for the present study

A straight mid-block section was selected in the present study. The study section was free from any obstructions/side frictions, grade or turning movements, intersections, speed-breakers, pedestrian crossings. To incorporate main objective of study, which was to analyse pure interactions between the vehicles operating on a straight road? For this video graphic method of data collection was used. A wide-lens camera was placed at an elevated foot over bridge foe a clear view of the vehicles. This data was analysed using Avidemux 2.6.1 software with ten further sub-fractions of a second, for more accuracy of time data. The fundamental traffic parameters speed, volume and density data were extracted from the video on a wide screen. The overall traffic was converted into five main types of vehicles for ease in the analysis, namely two-wheeler (2W), three-wheeler (3W), small car (SC), big car (BC) and heavy vehicle (HV). One category of vehicle was extracted at a time, to avoid the possible errors. Further, these macroscopic parameters of traffic were modelled in to micro-simulation software PTV VISSIM.

The computer-based simulation model was prepared and calibrated with the field observed results. Bangarraju et al. (2016) and Muniruzzaman et al. (2016) also studied the heterogeneous non-lane-based traffic of developing countries using micro-simulation technique.

2.1 Study Location:

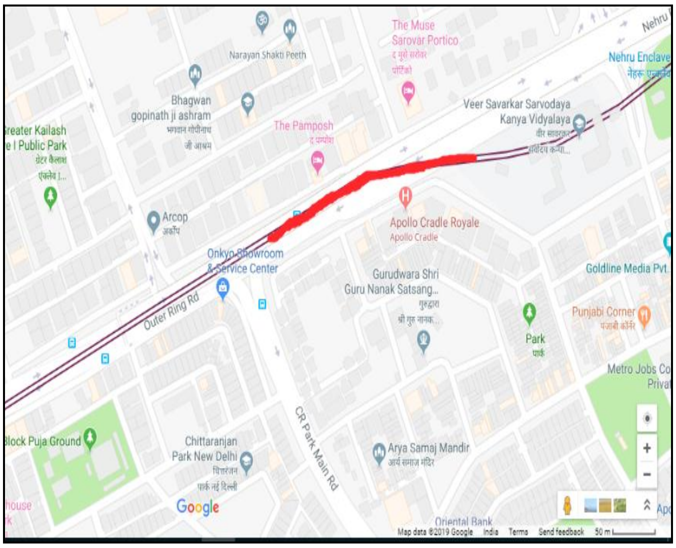

Fig. 2: Study stretch

The study stretch considered was free from U-turning or crossing movements of vehicles, there was not any direct access for vehicles to enter, merge or diverge near the study stretch, the stretch was fairly straight and of uniform width throughout. The care of side friction, which is often observed in urban intercity roads was also taken in consideration that, there were no curb side parking's at the stretch. These objectives were defined for selection of the study section, as pure interactions of the operating vehicles are to be studied. Also, the selected study stretch was free from gradient (firm) and curvature. The urban roads are also often face problems like undesignated crossings of pedestrians. To encounter the issues related to pedestrians, as discussed in the previous section, the study stretch was selected near a foot-over bridge (FOB) facility for pedestrians. By virtue of the FOB and divided roadway, the pedestrians were not observed to cross on the road section. Video graphic method of data collection was used to capture the wide-ranging variation of the vehicular interactions. Outer ring road from New Delhi was selected for the data collection purpose. Over the selected urban intercity arterial road, a 30 meters section was marked for studying the interactions of vehicles. A wide lenses high pixel resolution camera was used. The camera was placed on the edge of FOB in order to cover all three lanes (one direction) of traffic clearly. The figure – shows the Google image of the location of the study stretch. It is located at the Pamposh Enclave, greater Kailash, New Delhi.

2.2 Objectives of the study:

The aim of the present study is to prepare a well calibrated and validated simulation model, which is capable of imitating the actual field observed traffic conditions, with minimal errors. Broad objectives of the study are as mentioned below,

1. Calibrate and validate the simulation model.
2. Plot speed-flow-density relationship.
3. Evaluate the capacity and level of service of the study stretch considered.
4. Calculate the passenger car unit (PCU) for all vehicles, and find capacity in PCU/h.
5. Find the lateral clearance share for all possible combinations of vehicle pairs.
6. The lane wise headway distribution for the model
7. Evaluation of dynamic area of all vehicles, with all possible vehicle pairs adjacent to subject vehicle, and calculate dynamic PCU for all vehicles.
8. Comparison between static area PCU and dynamic area PCU values.
9. Obtain a relationship between speed and dynamic area/ lateral clearance of vehicles.

2.3 Level of Service (LOS):

Often capacity and volume of roadway are judged together, which causes confusion. The capacity of a roadway may be constant. But the term volume is varying. It varies with different time durations even within a day. The traffic volume observed at peak hours is considerably different than that it is observed at afternoon off-peak hours. This relation between volume and the capacity is used to relate the service experienced by the traffic. Volume can be termed as a quantitative approach to judge the traffic, but the capacity is however a qualitative approach. The term Level of service (LOS) defines the quality offered by the traffic facilities to its users. It is mainly divided into six types, ranging from A to F. A refers to the best quality of comfort and LOS-F is the worst conditions experienced by the users. The volume and capacity (v/c) ratio are one of the parameters to represent the quality offered by the system. The operating speed and travel time are the best representatives of LOS. But the present study focuses on the v/c ratio criteria. Table 5 represents the various LOS and their desired ranges of traffic characteristics.

Table 1: LOS and respective characteristics

LOS	K(veh/km/lane)	FFS(km/hr)	v/c ratio
A	0-7	120	0.35
B	07-11	120	0.55
C	11-16	114	0.77
D	16-22	99	0.92
E	22-28	85	1.0
F	>= 28	<= 85	>= 1.0

The present study focuses on analyzing the traffic at LOS-C, LOS-D and LOS-F i.e., from moderately low traffic to congested conditions observed on road. The obtained values of speed, flow and density and capacity of roadway were utilized further to prepare a simulation model. Simulation is a technique through actual field conditions can be addressed which are already designed, to be designed, planning or erection of a proposed model, feasibility study, etc. In the present study a simulation model was prepared and calibrated with the speed, volume and density values obtained from field. As these three are particularly the most basic and fundamental characteristics of traffic, it is believed that a model representing these values with minimum errors is said to replicate the actual interactions similar to that observed from field conditions.

3. DEVELOPMENT OF SIMULATION MODEL

Simulation tool is widely being used in transportation industry from past couple of decades for testing the control logic and to check the performance of system. Although there are lots of platforms are software available in the market, PTV VISSIM has achieved popularity widely in the industry. Its attractive animation and user-friendly interface have gained the world-wide status and being widely used among the developed and developing countries. It is widely used in the industry for corridor studies, system performance analysis at bottlenecks, to incorporate the control studies like contra-flow system, ramp metering, etc. delay and emission modelling at arterials and intersections (signalized/un-signalized). It also has applications in actuated signal controls and the reliability of platforms at light rail transit (LRT), etc. A combined platform of all such wide-ranging applications inbuilt in VISSIM has made it to be used in replacement of software packages such as LinSig, Synchro, Transyt, etc. Hence in the present study PTV VISSIM was used for studying and analyzing the traffic behavior on micro level. 3.1 Wiedemenn's car-following model.

3.1 Wiedemenn's car-following model:

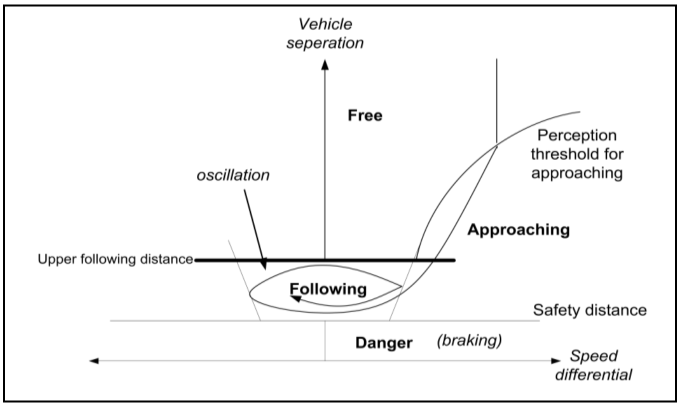

Fig. 3: Driving behavior states (Wiedemenn's car following model)

The driving behaviour characteristics in VISSIM is mainly categorised in to two, namely lateral behaviour of vehicles and the (longitudinal) car following behaviour. The driving behaviour defined in VISSIM is based on Wiedemenn's car following theory. The parameters are further divided in three types, namely No interaction, Wiedemenn-74 and Wiedemenn-99. The No interaction entry can be used to model the pedestrians flow, as the vehicles do not recognise any other vehicles moving adjacent to it. Wiedemenn-74 car-following model can be used to model the urban traffic and merging and diverging traffic. While, Wiedemenn-99 car-following model is suitable for modelling the expressways and freeways traffic, having no merging zones/areas. As the present study is based on the interactions of vehicles from the urban region (Pamposh enclave urban arterial, Delhi), the Wiedemenn-74 psychological car-following theory was used to model the drivers behaviour of the traffic. The driver is assumed to be in either offour states while driving a vehicle, namely free driving, approaching, following and breaking.

3.2 Estimation of Passenger Car Unit (PCU):

To represent the volume or capacity of a system in context to number of vehicles per unit time cannot be an appropriate method of representation as, the combined effect of number of 2W is completely different as compared to number of HV. Hence, in the present study the capacity of the study section is converted into equivalent number of PCU/hr. The method proposed by Chandra and Kumar (2003) was used to find the PCU values of vehicles.

$$PCU = \frac{Vc/Vi}{Ac/Ai} \quad \text{......................... (1)}$$

Where, VC, VI is the speed of passenger car (SC in the present study) and subject vehicle respectively, and Ac, Ai is the projected rectangular area of the passenger car and subject vehicle, respectively. As SC is considered as the standard passenger vehicle, all other class of vehicles were converted into the equivalent number of SC. PCU of a vehicle type is very dynamic in nature and it has impact of all variables that affect the driving behaviour of the vehicles. Hence, the PCU for each class of vehicle was calculated and the overall throughput of traffic stream was measured in PCU/hr. The Fig. 3.4 represents the PCU values for all class of vehicles.

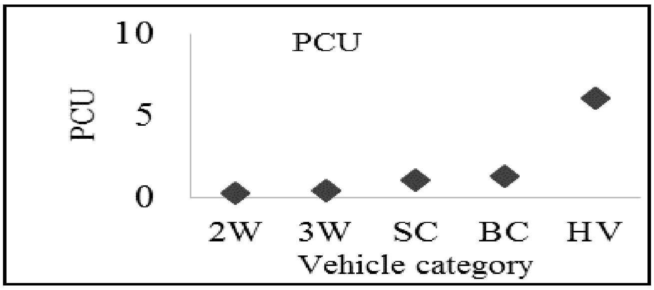

Fig. 4: Static PCU values by conventional method

3.3 Tools and Platform:

The basic model includes the modelling of links and network. In VISSIM interface the roads can be modelled using the links. Connectors (short lengthen links) are used to connect the two links with each other. The placement of a link can be made using the Bing maps or google maps feature, which is accessible from VISSIM. Particular study section on which the data has been collected can be directly accessed and modelled accordingly, which gives flexibility for planners to model the study sections effectively. The details of section are to be given as input such as, number of lanes; width of section, etc. The road section modelled is as shown in the Fig. 5.

Fig.5: Study section modelled in VISSIM

3.4 Calibration of driver's behavior parameters:

Calibration is progression to refine the model to replicate the observed the main aim of calibration is to satisfy the model objective to replicate the field conditions within the developed model. In the present study calibration was done by adjusting the driver's behavior parameters which are most important to modify the output of the model. Data to an adequate level of accuracy (with negligible errors).

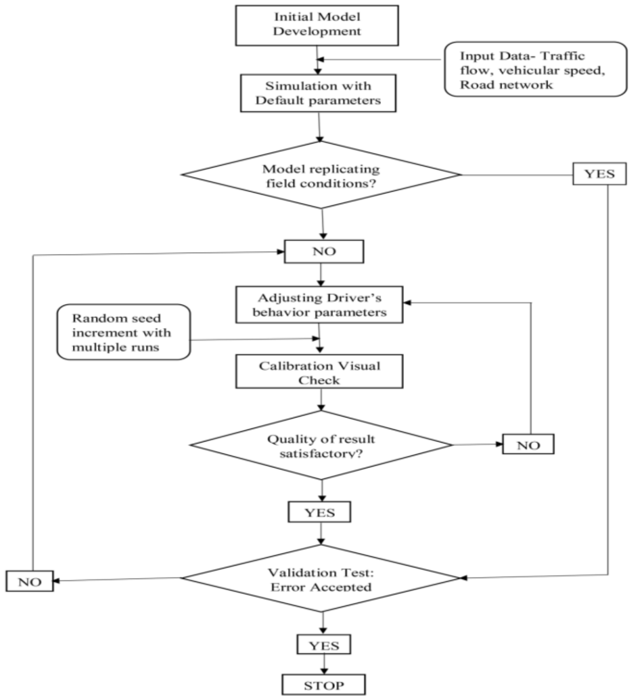

Fig. 6 Calibration model

VISSIM is by default a homogeneous lane-based traffic tool, developed by PTV-AG, Germany. It is based on the traffic conditions that observed in developed countries, especially from European and American continent. However, a heterogeneous non-lane-based traffic can also be modelled by a rigorous modification in driver's behavior parameters. This flexibility of VISSIM has mainly achieved world-wide popularity for simulating the traffic. Many researchers used VISSIM to model the heterogeneous traffic, mainly from the developing countries including India. (Siddharth and Ramadurai 2013)(Singh et al.2012a)(Srikanth et al. 2017)(Maitra et al. 2015)(Raj Khode 2016) simulated heterogeneous traffic for the Indian scenario. Hence, in the present study VISSIM is selected for simulation model development.

4. DATA ANALYSIS

The video graphic data collected from field was played on a large screen monitor in the laboratory. (Lu et al. 2016) also collected video graphic data for the analysis of the interactions of vehicles. For more accuracy of time data, and to avoid the errors in the measurements, the video was processed inAvidemux_2.6.1 software. Avidemux is an open-source video editing program designed for video editing and video processing. It is a free video editor designed for simple cutting, filtering and encoding. One second was further divided into ten microseconds in the software interface, which was noticeably useful to erect the accurate readings of time data. The lines were marked at the entry and exit of section, and the time difference between these two points was used to calculate the speed of vehicles. The speed calculated for this section was considered as the average speed over the arterial road, as there were no obstructions or hindrances to the traffic within the section. Various categories of vehicles were observed from the video, which were converted into five main categories for simplicity in the analysis. The categories of vehicles defined in the present study were namely two-wheeler (2W), three-wheeler (3W), small car (SC), big car (BC) and heavy vehicles (HV). The proportion and the average dimensions considered in the present study are as shown in Table 2

Table 2 Average dimensions and proportions of vehicles

Vehicle Type	Proportion (%)	Average dimensions		
		Width(m)	Length(m)	Area(m^2)
2W	30.96	0.85	2.00	1.70
3W	9.56	1.08	2.36	2.55
SC	47.83	1.69	3.89	6.57
BC	7.73	1.86	4.61	8.56
HV	3.92	2.83	10.88	30.79

The two-wheeler was composed of all motorized two-wheeler vehicles (excluding bi-cycle). Three-wheelers consist of motorized three-wheeler vehicles often observed in the urban regions. The car traffic was divided into two main classes. SC consists of sedan, prime-sedan, and hatchback cars moderately having the engine capacity up to 1000 to 1200 horsepower. While, BC consists of sport utility vehicles (SUVs) having relatively more occupancy and engine capacity as compared to SC. The length of BC vehicles is also comparatively more than those of SC. Lastly, buses, trucks, tempos, multi-axle vehicles and containers were converted into a single HV category of vehicles, as their speed and acceleration characteristics are nearly similar. The percentage share of different vehicle classes observed in the traffic stream is shown in Fig.7.

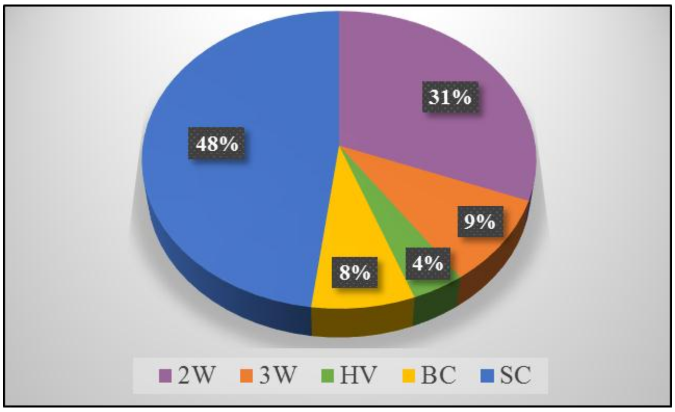

Fig. 7 Proportion of vehicles in traffic stream

4.1 Calibrating Speed flow relationship:

For establishing the relationship between speed, flow and density for the traffic stream, the speed value required for comparison is the "stream speed". The stream speed in the present study is calculated by taking the wetted average of number of vehicles passing the section in one minute and respective speed of the vehicle was multiplied for consecutive five-minute data, for all vehicle categories. Lastly, the average of this wetted average speed data was taken and it was considered as the average speed of the traffic stream. Similarly, the per minute results were obtained from simulation model and were compared with field observed data. Further, by modifying the driving behavior parameters the desired field observed values of density and flow were obtained from the model. This process needed a rigorous and repetitive adjustment of the driving behavior parameters, until the anticipated results are not obtained. The similar speed-flow relationship for simulated results was obtained and compared with the field observations. Also, ANOVA test was applied for the combined stream speed of the traffic, volume (veh/h) and density (veh/km). Fig. 5.8 shows the comparison between the simulated and field observed results.

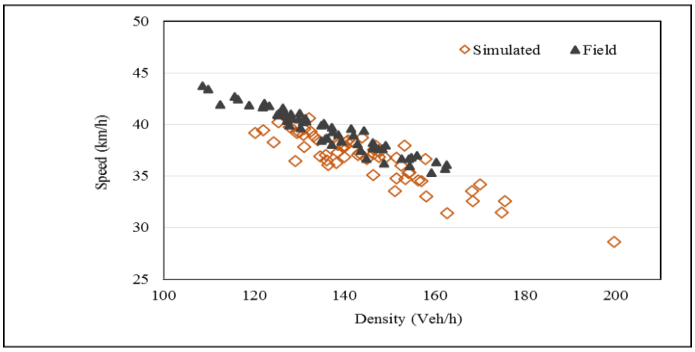

Fig.1 Comparison of field-observed and simulated speed-density relationship

The most basic and fundamental parameters of traffic are considered to be the speed, density and the volume. Hence, in the present study the comparison between the field observed and simulation results was done by associating the degree of similarity between the speed, density and volume of traffic of both. In the subsequent part of the study, the comparison of speed-flow and flow-density is also presented. From Fig. 5.8, it can be observed that the results obtained from the simulation model are nearly matching with those of the field observed data values. As similar to speed-density, speed-flow and flow-density relationships were also calibrated and plotted. This comparison was checked graphically, but to check for more accuracy and reliability of the simulation model results, ANOVA test between the three fundamental parameters speed, density and volume together. If there is any significant difference within the dataset is checked using the test. The Table 5.4 shows the results of ANOVA test.

Table 3 ANOVA test results for field observed and simulated data

	P-value	P-crit	P>P-crit	F-value	F-crit	F<F crit
Flow (Q)	0.3568	0.05	Yes	0.856	3.921	Yes
Density (K)	0.8607	0.05	Yes	0.031	3.991	Yes
Speed (V)	0.0884	0.05	Yes	2.969	3.949	Yes

4.2 Model Validation for PCU values:

To check the reliability of the calculated PCU values for the developed simulation model, the observed composition of heterogeneous traffic was made run for one hour into the developed simulation model with the previous volumes, obtained from the various V/C ratios considered for the study. Further, this traffic was converted into the PCU/hr traffic using the PCU values obtained for specified vehicle class at particular volume. Accompanying to this, for same volumes considered, the total vehicle input given to the simulation model was of only SC. i.e. the standard passenger vehicle considered for the study. Mardani et al. (2015) and Arasan and Arkatkar (2011) also checked the validity of the simulation model using the similar passenger car as standard vehicle, as car only traffic. The results obtained from the equivalent PCU/hr volume and the SC only volume from the simulation was compared. The t-test was applied to the obtained results. The t_0 value obtained was 3.08 and the $c_{critical}$ value was 5.73 which is greater than the $t_{0,}$ hence it proves that there is no significant difference between the two data sets. Hence the simulation model and the PCU values both are said to be valid and reliable, at specified volume levels. The Fig. 5.12 shows the comparison of the SC only data and PCU/hr data of the volume, obtained at various volume levels.

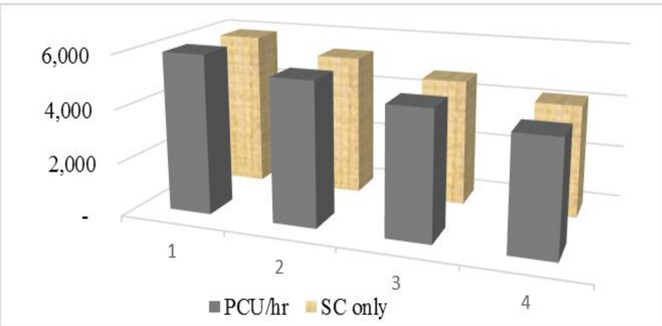

Fig.9 Comparison of heterogeneous (PCU/hr) and SC-only traffic

4.3 Speed-Lateral Clearance Analysis:

Once the simulation model was able to replicate the field observed heterogeneous traffic effectively (with negligible errors), it can be further used for its desired application purpose. In the present study, the calibrated simulation model is used to study the vehicular interactions of heterogeneous traffic.

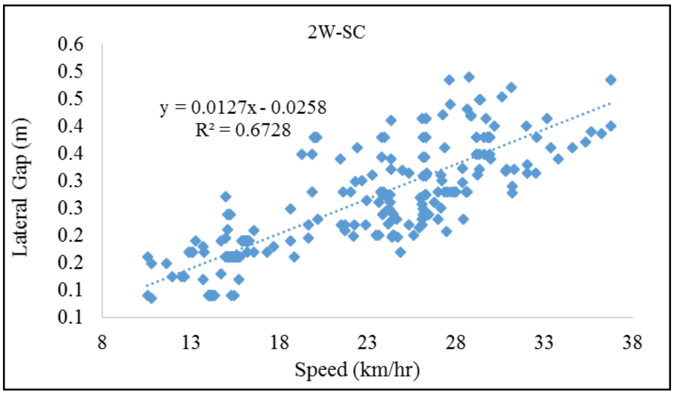

Fig. 10 Speed vs Lateral clearance for 2W and SC

It can be observed that, HV had least speed, but maximum share of lateral clearance compared to others. Completely opposite to this, 2W drivers were observed to have overall minimum clearance values. The picture of lateral clearance share can be made clearer by dividing the data into the percentile values. The actual behavior can be accessed using discrete unique percentile values of all class of vehicles together. The lateral clearance shares with all vehicles considering one vehicle as subject vehicle at a time are shown for total five classes of vehicles in Fig. 10 The combined data with all other class of vehicles is plotted considering each vehicle as a subject vehicle.

Abrupt variation can be observed among all the vehicular pairs among each other's hence it is difficult to find a relation between speed and lateral clearance of vehicle. Because, at any speed, any lateral clearance value can be observed. However, an overall increasing trend of lateral clearance was observed for 2W, SC and BC as the subject vehicles. But in case of 3Ws, due the most vibrant and dynamic lane changing behavior, the lateral clearance share with the traffic stream is of not any relevance. Even at higher speeds up to 45 km/h, lateral clearance observed was 0.8 meters in some cases and also 0.15 in few cases. This variation is observed due to the reckless driving of3W drivers. Once the lateral clearance share variation for all class of vehicles was captured, the objective of lateral clearance was over. Further, this lateral clearance of vehicles was made used to calculate the dynamic effective area of vehicles.

The variation of cumulative frequency distribution of effective area, for all vehicle classes with the possible pairs of vehicles adjacent to each other is illustrated in the following Fig. 11.

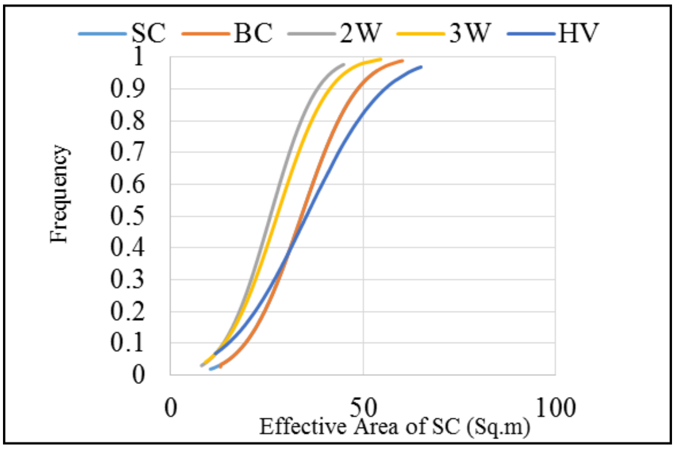

Fig.11 Effective area SC CDF plot

5. CONCLUSIONS

General: The lateral placement and interaction of vehicles is one of the important factors which results in decrement of the overall throughput of the roadway system. Hence a comprehensive study has been made in the present work to relate the speed and the lateral clearance share between the vehicles.

1. The lateral clearance of vehicles is a very dynamic characteristic of vehicular traffic, and it is function of speed, type of the vehicle adjacent to subject vehicle and a specific lane occupied by subject vehicle.
2. From the brief review of literature, it has been observed that PTV VISSIM software is capable to model homogeneous as well as heterogeneous traffic conditions, by some modifications in the driving behavior parameters.
3. The capacity of the urban arterial road selected for study was obtained as 5957 veh/hr. (6034 PCU/hr).
4. The six-lane divided urban arterial road was observed to have v/c ratio as 0.91 and hence the Level of Service of the system was obtained as E.
5. As driver's behavior is a very intricate parameter, the calibration was done by using the basic fundamental parameters speed, density and volume of the vehicular traffic.
6. There was a large variation in speed ranges observed for all categories of vehicles, hence their percentile speeds were considered for the further analysis.
7. The S-curve representing the speed profile of vehicles was modelled to calibrate the speed of individual vehicle classes in VISSIM.
8. The stream speed was observed to follow the Wake-by distribution for the kerb-side and middle lane; However, the speeds of outer lane were slightly varying hence were observed to follow the Hyper-scent distribution.
9. Wiedemann-74 car following model was used to model the mixed traffic with higher degree of heterogeneity.
10. The lateral clearance and headways of vehicles were made used to calculate the instantaneous (imaginary)

effective area of vehicles that is attained by each driver for its safe maneuverability in the traffic stream.

11. Variation of effective area with the corresponding instantaneous speed was analyzed, and it was observed that with increased speed values, the effective area required for vehicles also tends to increase.
12. The PCU of vehicles as calculated from conventional method and (effective area approach) dynamic PCU method were compared, and it was observed that for 2W, 3W and BC there was not much difference observed, but for HV the PCU values had much difference.

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